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WHAT EVOLUTION IS

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WHAT EVOLUTION IS

BY

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PREFACE

THE growing popular interest in evolution calls for a simple statement concerning this doctrine. Such a statement should be as brief as is consistent with right understanding, and should be to the point. In view of the animated and heated discussions that have been excited by the present situation, this statement should be free from prejudice and partiality. It is from this standpoint that the following pages have been written.

No fundamental doctrine such as that of evolution can be rightly considered without taking into account its full bearings on the whole of organic nature. Plants and animals, with all their intricate interrelations, afford the materials for this theme. Man as the most complex of animals

must find his nature elucidated through evolution if this doctrine is to maintain itself. What its value is in this respect must be judged by each reader.

That the illustrative examples and other like materials in the present volume are chiefly from zoölogical sources is due to the fact that the writer is a zoölogist. It is scarcely necessary to add that botanical materials afford the same kind of evidence as that given in the body of this text and might have been utilized in the same way that the zoölogical examples have been.

It is the object of this volume to present a brief, readable account of the main facts of evolution, that the ordinary reader may acquaint himself with what may be called the elements of the subject. That so large a topic as evolution can be adequately

treated in a volume of the size of the present one is quite inconceivable, and yet such an account as that which follows may at least outline the subject and in this way prepare the reader for further inquiry.

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I

INTRODUCTORY

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Evolution is a term that has been used in a great variety of ways. We speak of the evolution of the stars, meaning thereby the process by which stars have grown from gaseous masses to incandescent bodies, such as our sun, and finally to the cold inert conditions of stellar death. We speak of the evolution of the earth, in that we picture the growth of that body as a part of the solar system whose central element, the sun, yields the energy by which the earth is moulded. Under the varying heat of this luminary our atmosphere is made to move as wind, water is evaporated and condensed, continents are eroded and dissected, materials are disintegrated, transported, and deposited — in short, the surface of the earth is put under con-

tinual flux and change. Thus the present configuration of oceans and of continents, of mountains and of abysses, is looked upon, not as something stationary, but as due to operations whose titanic energies have been exerting themselves through untold ages in the past and will continue so to act far into the future. These happenings, and such as occur among the stars, constitute what may be called cosmic evolution, a body of change which in the nature of things preceded life and was, in a certain sense, preparatory to it. It is the plan of this book, not to deal with this type of evolution, notwithstanding the fact that cosmic evolution is intimately bound up with the origin of living things, but to consider exclusively the kind of evolution that has to do with organisms, with plants and animals. Such a type of evolu-

tion may be called organic, as contrasted with what has just been spoken of as cosmic.

Organic evolution, dealing as it does with living organisms, has a set of problems quite its own. Although the body of a plant or of an animal contains no chemical element not found in the earth, and the energy in such living bodies is subject to the same laws that govern the inorganic, plants and animals have superimposed upon their fundamental cosmic properties, other properties more or less peculiar to themselves. Thus all plants and animals, like other bodies about us, are subject to the law of gravitation and to other laws of a purely physical and chemical nature; yet these plants and animals grow, reproduce, react, and respond in ways which are not entirely consonant with the chemistry and physics of the

strictly inorganic. They have, in addition to the chemistry and physics of lifeless nature, a chemistry and physics more or less their own. It is in this way that organic evolution differs from simple cosmic evolution, for organic evolution is a general operation among plants and animals some aspects of which are not to be met with in the inorganic.

Organic evolution, though a well-unified field in biology, can be profitably treated under two heads. The first of these has to do with the doctrine of descent with modification — the belief that plants and animals of particular kinds have descended by gradual modification from preëxisting plants and animals of very different kinds. This belief, which is often spoken of as if it were the whole of evolution, is supplemented by what may be treated under a sec-

ond heading, a group of doctrines that have to do with the way in which descent with modification has been accomplished. Granting that plants and animals have arisen by the modification of earlier forms, what have been the driving forces in nature that have induced this modification? This is a newer and much less certain field of work than that which deals with the simple fact of change or transmutation in organisms. It includes a consideration of Lamarckism, of Darwinism or the theory of natural selection and such subordinate theories as sexual selection, of orthogenesis, of the mutation theory, and of a host of other views which from time to time have been advanced as explanations of descent with modification. In the following pages, after some brief historical comment, the subject matter will be dealt with

under the two general headings just mentioned: evolution as descent with modification, and the explanations that have been offered for this process.

II

HISTORICAL

HISTORICAL

The idea of evolution is often looked upon as a comparatively modern one. As a matter of fact, it reaches back into remote antiquity. Most races of primitive man believed in some vague way that they had kinship with the lower animals. Many of the clans of American Indians used animals as their totems. Among the Indians of the northwest coast the bear, the raven, and the beaver were used in this way, and in New England the wildcat, the wolf, the muskrat, the squirrel, the porcupine, and the frog were similarly employed. Although these totems were primarily signs of the clan and were used as such, particularly in religious observances, they were in many instances invested with an ancestral aura, and the clan

was supposed in some vague way to have descended from the animal concerned. Most primitive human beings seem to have had some such traditions as these about animals, but, of course, in no case could these views be said to have more than remotely implied an evolutionary conception. They merely show that in primitive man kinship with animals was not an unknown idea.

To certain Greeks organic evolution in the modern sense came nearer to being a reality. Thus the great physical philosopher of the Ionian School, Anaximander (611–547 B.C.), is credited with having held to a form of general evolution in which man was especially involved. Anaximander was apparently impressed with the inability of man in his early stages of life to care for himself, and was thereby led to conclude that

human beings in the beginning must have been very different from what they are at present. He is even believed to have assumed for them an aquatic ancestry, perhaps fish-like in character. Anaximander's views were often quoted, and thus classical antiquity must have had some idea of the evolutionary doctrine.

But the serious advances in this body of opinion date from the last two centuries. Throughout the early part of this period uncertain rumors of an evolutionary kind were continually heard; and as time went on, these rumors became more and more distinct. With this growth in definiteness opposition took on a more final shape. Thus Linnæus (1707–1778), who may be said to have established systematics by publishing in his "Systema Naturæ" a classification and description of all plants

and animals known in his time, believed firmly in the immutability of species and declared in favor of the biblical account of special creation. According to him there are as many different species of plants and of animals on the earth as there were different forms created by the Supreme Being in the beginning. This view, based upon the account in Genesis, was thus set in strong contrast with that of the origin of species through descent with modification.

The first radical exponent of modern organic evolution was Lamarck (1744–1829) who published in 1809 his "Philosophie Zoologique." In this volume Lamarck set forth a plea that the plants and animals of to-day had arisen by the modification of preexisting forms, and he further advanced an hypothesis as to the way in which this change had come about.

His views were ably seconded by a number of the most distinguished savants of his time, among whom may be numbered the great Goethe. Of Lamarck's confrères Geoffroy Saint-Hilaire took up the subject in public discussion with Cuvier, perhaps the greatest naturalist of his day. Cuvier, whose opinions were anti-evolutionary, resisted with all his strength and authority the rising tide of new opinion and succeeded in checking its flow, for it was generally concluded at the end of the contest that descent with modification must be permanently abandoned.

For some decades the storm subsided, for the appearance of the little volume entitled "Vestiges of the Natural History of Creation," published by Robert Chambers in 1844, was only a ripple on the surface. Then in 1859, with the publication of Dar-

win's "Origin of Species," the storm broke afresh, this time not to be turned aside till it had swept the shores clear of the wreckage of old ideas.

Everyone knows the great public upheaval that followed the appearance of the "Origin of Species." The scientific world had been prepared for it by a paper on the theory of natural selection, published by Darwin and Wallace in the preceding year; but considering the long period of relative quiescence that had preceded 1859, even scientists must have been startled at the uproar that broke forth. Darwin and his able coadjutor, Huxley, had the double task of showing to the world that, in contrast with special creation, descent with modification had taken place, and that natural selection was the driving force behind this process. In the

days of Lamarck the chief question was on the modifiability of species, and on this first line of attack the forces of evolution received for the time being a serious setback. But under Darwin and Huxley a new offensive was launched, and after a vigorous campaign both objectives were attained. It is to the credit of Charles Darwin, and his body of able supporters, that the scientific world was finally brought to accept the principle of descent with modification, and natural selection as the means whereby it was accomplished.

The evidence that convinced the world in Darwin's day that descent with modification, and not special creation, was the means of peopling the present globe with its variety of living forms was meager in the extreme as compared with what might be drawn upon to-day, but it never-

theless covered the ground and may be profitably looked into now, since it still affords the real support on which the doctrine of evolution rests. This body of evidence comes from five important fields in biology: comparative anatomy, embryology, the study of fossils, zoögeography, and the nature of rudimentary organs.

III

EVIDENCE ON EVOLUTION

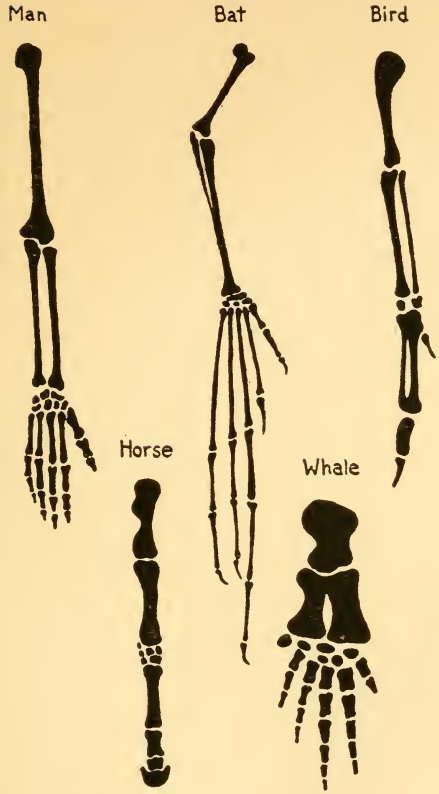
EVIDENCE ON EVOLUTION

1. FROM COMPARATIVE ANATOMY

An important body of evidence that bears on the evolutionary problem comes from the field of comparative anatomy. A little over a century ago the school of comparative anatomy was founded by Cuvier (1769–1832), who, though an anti-evolutionist, showed that animals in their structure were not immensely diverse, but conformed to general plans or types of organization. From this standpoint each animal could be said to represent its type, subject to such modifications as its special mode of life called for. Thus under the enormous diversity of animal forms there was in reality a more or less hidden uniformity.

This principle of type organization

is abundantly illustrated by many sets of organs. For instance, the human arm is composed of parts that recur in the corresponding organs in other animals. The arm of man, as shown on page 23, contains four sets of bones: the single bone of the upper arm, the pair of bones in the forearm, the group of small wrist bones, and the series of elongated bones in the five digits. All these groups of bones recur with great regularity in the foreleg of the cat, of the turtle, and of even so lowly organized an animal as the frog. The wing of a bat, when it is examined, is found not to be constructed upon a plan peculiar to itself, but to be a modification of the type of structure already described for man, in that the single bone of the upper arm is present, as are the pair of forearm bones, the wrist bones, and, enormously elongated to carry the


Man
Bat
Bird
Horse
Whale

web of the wing, the finger bones. In the bird, unlike the bat, the expansion of the wing is due to feathers but the skeletal axis that supports the feathers is formed from a set of bones such as occur in the human arm, except that the fingers are reduced in number and bound together to serve as a supporting axis for the larger plumes. The flipper of a whale or of a porpoise, superficially so unlike the human arm, nevertheless shows closely compacted within it the bone of the upper arm, the two forearm bones, wrist bones, and finger bones. In the foreleg of the horse the bone corresponding to that in the upper arm of man is hidden in the flesh of the animal. This bone is followed, however, by the two bones of the forearm, fused together, by the wrist bones, which are situated at what is popularly called the knee of the horse,

and by a row of bones which represent the middle finger of man. These bones in man are four in number, counting the deep-seated long bone in the palm, and this number is exactly reproduced in the horse, in which the last member of the series carries the hoof corresponding to the human nail. The front leg of the horse not only rests on what is equivalent to the enormously enlarged middle finger of man, but it contains, on either side of this digit, relatively inconspicuous splint bones which represent our index and our ring fingers.

By the comparative method it is thus possible to demonstrate that such apparently diverse organs as the arm of a man, the wing of a bat, and the foreleg of a horse are similarly organized and are merely modifications of one type of structure.

Animals and plants abound on

every hand with series of parts in which the elements are related, as in the examples just described, and it is one of the achievements of the comparative method that it has thus yielded incomparably rich and significant material for philosophical biology. By its means anatomy has been lifted from a discipline of dead description to a science rich in problems and resources.

This advance in method had an immediate and decisive bearing on the evolutionary question. If organisms were separately created there would be every reason to expect that they would be constructed upon individual plans, and not the least ground to anticipate in them an underlying common type of structure. If, however, they have evolved from a common ancestry, precisely such underlying similarities might be ex-

pected. The human arm, the foreleg of a quadruped, the wing of a bird, and the flipper of a whale have a common plan of organization because these animals have had a common ancestry. Thus the science of comparative anatomy yields results that support most completely the evolutionary idea, and that give no ground for the assumption of special creation. It is a remarkable fact that Cuvier, who, as already observed, was a strong anti-evolutionist, should have been instrumental in founding and in partly developing a school that in the end yielded such important evidence in favor of descent with modification.

2. FROM EMBRYOLOGY

THE science of embryology deals with the growth of animals from the egg to the adult, and this science, though of comparatively recent origin, has had an important bearing on evolutionary problems. It is a commonplace that, in the development of any animal, the creature does not start life as a miniature of what it is finally to be and then slowly enlarge until it reaches adult proportions, but it begins life in a state very unlike its adult condition and only gradually assumes an outline that is associated with its final form going through a series of changes, often very profound, till it finally arrives at its mature state.

Most common animals afford examples of this kind of growth.

Frogs, for instance, lay eggs and from these are hatched, not frogs, but tadpoles which eventually, through a series of rather complicated bodily changes, reach the condition of an adult frog.

The remarkable peculiarity of this kind of growth is that, during the steps in its progress, the young animal often shows striking resemblances to other animals. Thus, in the instance just given, the tadpole of the frog has unquestionably fish-like characteristics. Instead of having front and hind legs for locomotion as in the adult frog, the tadpole moves about by means of a flattened tail in a way similar to that of a fish. Moreover, the tadpole has in its neck a system of gills by which it breathes precisely as a fish does. As development goes on, these gills are gradually absorbed and are replaced by

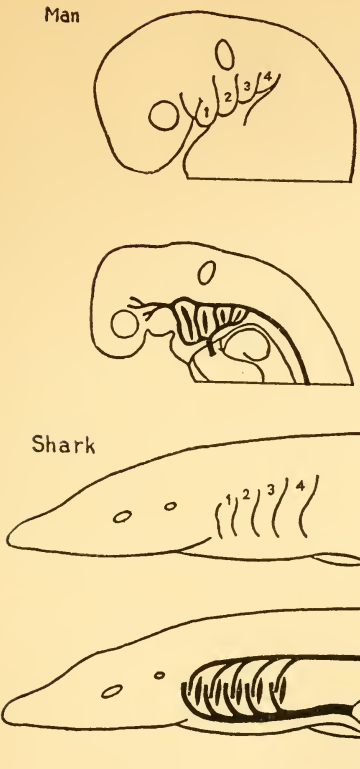
lungs when the tadpole approximates the state of the frog. But before this metamorphosis has taken place the tadpole, in structure and in activities, recalls in many important particulars the state of a fish.

Examples of this kind may also be found in the course of human development. When the human embryo is a small fraction of an inch in length a definite number of narrow transverse clefts appear on its neck as shown in the uppermost figure on page 33. These clefts lead into the throat and correspond in position to the gill openings of fishes. Moreover the supports between the clefts, the arches, which are numbered in the figure, carry large arteries resulting from the division of the main blood-vessel that emerges from the embryonic heart, just as the gill arches of fishes are supplied by large vessels from the

heart of the fish. These embryonic organs in man never serve for breathing as the corresponding parts do in fishes, but in gross structure the human gill arches recall in a most striking way the gill system of fishes. As the development of the human embryo proceeds, the gill clefts are obliterated, excepting the first one which is retained in forming the aperture of the external ear.

Thus the frog and man and in fact all the higher vertebrates show in a temporary way gill clefts and gill arches, both of which are the permanent possessions of the fishes.

That higher animals should, in the course of their individual development, exhibit temporarily features that are permanent in lower animals, seems to be a rule of organic growth. It certainly is abundantly exemplified in many forms. Thus in all


Man
1
2
3
4
Shark
1
2
3
4

true backboned animals a notochord, or supporting rod, precedes in development the real backbone of these forms and is replaced by this bone, except in the very lowest fishes where the notocord is the permanent and only organ of support. Another example may be found in the embryonic human being where small ribs occur attached to the neck vertebrae. As development advances these ribs fuse with the vertebrae and are thus lost to view, but in lower animals, like the alligator, neck or cervical ribs are persistent throughout life. Again all animals that reproduce sexually pass through an egg stage in which they are, for the time being, a single cell. This state is a permanent condition in the simplest animals, the protozoans, which are very usually only single cells. Innumerable examples such as these might easily be given.

The peculiarity of development, that higher animals pass in a temporary way through stages that are permanent in lower forms, has long been recognized as a characteristic feature of general growth. It has sometimes been dignified as a law of development and has been designated, in honor of the father of modern embryology, von Baer's law. As such it was strongly advocated by Louis Agassiz. In a more descriptive way it has been spoken of as the law of recapitulation, for the reason that such features in the development of an animal as those already alluded to recapitulate, in a rough way, the racial history of the animal concerned. Thus the presence of gill slits in the embryo of the human being indicates that a gill-breathing animal is to be included in our remote ancestry. As Huxley facetiously remarked in dis-

cussing this question years ago, each animal in its development climbs its own ancestral tree.

The facts associated with the law of recapitulation are quite meaningless from the standpoint of special creation, but from that of descent with modification they receive a simple and adequate interpretation. A developing animal shows temporary resemblances to lower forms, because these forms represent steps in its own racial history.

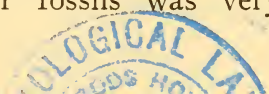
3. FROM GEOLOGY

The evidence on the evolutionary problem to be drawn from geology turns largely on the question of fossils. A fossil is anything dug from the earth. Specifically fossils are bones, shells, or even delicate structures such as ferns and the like, that have been more or less converted into stone and have been exhumed from their hiding places in the rocks.

The ancients were acquainted with fossils, but they regarded them in a light very different from that in which the modern naturalist looks upon them. Fossils were believed by the ancients to have had something to do with nature's formative processes. These early observers were, for the most part, believers in spontaneous generation. They accepted

the view that new organisms, plants and animals, were being continually produced by nature, that fish, frogs, worms, and the like were being formed continually from the mud and slime in the bottoms of ponds, that maggots were being generated spontaneously in decomposing meat, and that parasitic worms were being produced in the interior of the animals whose bodies they inhabit; in short that the process of spontaneous generation pervaded nature generally. They were not conversant with the modern idea, arrived at after long experimentation, that all living things come from preëxisting living things and that none are formed *de novo*. They held that mother earth was continually producing new life from her own substance.

With this doctrine in mind, their interpretation of fossils was very



different from that given by the modern naturalist. When they discovered the impressions of shells in the rocks of the mountainside they recognized at once the inappropriateness of the situation, and they believed that they had before them evidence of nature's unsuccessful effort to produce new life. She, in her prodigality of productiveness, had started the formation of an aquatic animal on a mountainside and, in consequence of the unfavorableness of the site, the process had failed of completion and a mere trace of its beginning was thus left stranded in inhospitable surroundings.

This general view of the nature of fossils was current for many generations, but as early as the fifteenth century, Leonardo da Vinci (1452–1519) recognized that shore lines shifted, that the earth's crust was ele-

vated and depressed, and that what was once sea bottom, with its myriads of marine plants and animals, might well become mountainside with its contained fossils. Gradually the opinion grew that all fossils were the remains of once living organisms, and this doctrine, advanced through the efforts of such workers as Fracastoro, Steno, Hooke, and others, had gained complete acceptance in the days when Lamarck (1744–1829) and Cuvier (1769–1832) were founding modern paleontology.

Concurrent with the growth of the new ideas about fossils came the conceptions of stratigraphic geology. Rocks not only contain the fossil remains of once living organisms, but the underlying rocks hold remains of an older date than do those above them. Such a sequence of fossils, as is implied by this view, was advocated

by Woodward (1665–1728), Valisnieri (1661–1730), Smith (1769–1829), and especially by Cuvier (1769–1832). Cuvier further recognized that the older rocks contained fossils of a simpler type than the more recent ones did, and he explained this difference by assuming that periods of cataclysmic destruction alternated with periods of special creation. This doctrine was carried to an extreme by d'Orbigny (1802–1857) who claimed for the past some twenty-seven such alternations. But the idea of cataclysmic alternations was defeated by the school of uniformitarians, whose advocates, like Lyell (1797–1875), saw in the present forces of nature an explanation of the past and supported the idea of continuity, not interruption, in the organic series. By these steps the modern conception of fossils and

their significance was reached; they are the remains of once living organisms, and they disclose a continuous and real history of plant and animal life.

When this history is looked into, it is found to have, as might be expected, a profound bearing on evolutionary matters. It is by no means easy to determine how long living things have existed on the earth. Estimates vary from a hundred-million to two thousand-million years. But from an evolutionary standpoint such enormous periods, and even such differences in the estimates, are not so significant as the kinds of organisms that are shown to be present at different periods in the earth's history and the sequences that this history discloses. Sketched very broadly, it may be said that during about the first two-thirds of the period in which life has been on the globe

only invertebrates were present. These include sponges, corals, starfish, worms, crustaceans, insects, brachiopods, snails, clams, and other shellfish. Vertebrates, or backboned animals, first arose about the beginning of the last third of the period of life on the globe, and the earliest fossil representatives of this group were the fishes. These were followed, near the opening of the last quarter, by the amphibians which were succeeded by the reptiles, the mammals, and the birds in the order named. Man has been present on the globe during somewhat less than the last hundredth of the total period of living things.

When this sequence is reviewed it is seen at once to present a reasonable plan. Invertebrates precede vertebrates, fishes antedate amphibians and these in turn come before reptiles, mammals, and birds. Man appears

only near the very end, long after the group of which he is a member, the mammals, had established itself.

The sequence of forms that is here portrayed is an orderly one and the order is such as would be expected on evolutionary grounds. Had special creation been the rule of nature there would have been no reason for invertebrates to have preceded vertebrates in their time of appearance, or for fishes to have come before amphibians and the like. But this order of appearance being such as it is, one must conclude that this aspect of the fossil series gives unequivocal support to the evolutionary view.

Facts of the kind that have just been narrated were well known in Darwin's day. Since that time the study of fossils, and particularly of vertebrate fossils, has enormously expanded. Huxley in his time was

much interested in the fossil series illustrating the evolution of the horse. As is well known, this animal can be shown to have descended from a small multi-toed creature of the approximate size of a fox. In the early days of the evolutionary controversy this was the one series of developing forms that the paleontologist could point to with assurance. To-day scores of such series are known not only in the vertebrates but in the invertebrates. Even with man the call for the missing link seems to have subsided, for the sequence in so many of the fossil series is so nearly complete that it seems to be only a matter of diligence and time till the fossil record of any important line can be brought to light. The imperfections in the fossil series are no longer interpreted as real and significant breaks but as interruptions sooner or later to be filled as science advances.

4. FROM ZOÖGEOGRAPHY

The past and present distribution of animals on the surface of the globe has important bearings on the evolutionary problem. Animals are not scattered in a haphazard fashion over the earth, but show a marked regularity in their occurrence. This can be well illustrated by what is known of the mammals. The group of mammals is made up chiefly of the common beasts of the field and forest, but it includes also such exceptional forms as the bats, among aërial creatures, and the whales and porpoises of the sea. Mammals have warm blood, they produce milk with which they nourish their young, and they are provided with more or less hair.

Almost all the mammals bring forth their young in a highly developed,

active state. Two of them, however, the Australian porcupine and the duckbill, lay eggs. These two mammals, in addition to the habit of laying eggs, have many primitive characteristics. They constitute the lowest group of this class of animals. They are commonly designated as monotremes. The remarkable feature about them, from the standpoint of the present discussion, is that they are not found broadcast over the earth but are limited to a very distinct zoögeographical area, the Australian region. Thus the total representation of this striking group of forms is restricted to a small part of the globe.

The Australian region is not only the habitation of the monotremes; it is also the home of the marsupials. These are mammals, such as the phalangers, the wombats, and the kangaroos, the females of which are

commonly characterized by the presence of a pouch on the abdomen. This pouch, which contains the milk glands, serves as a receptacle for the young after their birth. Most persons have seen in our zoölogical gardens the female kangaroo with her offspring and have noticed how the young, when alarmed, run to the pouch, enter it, and are carried off by the mother. The marsupials, like the monotremes, are very primitive mammals. Excepting the American opossums and one other pouched mammal in South America, all marsupials are limited to the Australian region. No marsupial occurs in Eur-Asia or in Africa. Thus the marsupials, like the monotremes, illustrate a common peculiarity of animal distribution, namely, that many large and important groups are limited to well circumscribed and often relatively small areas of the earth.

This topic is still better illustrated if we take into consideration the distribution of fossil, as well as of living forms. Again the mammals may serve as illustrations. Sloths and armadillos constitute a group of mammals very striking in their distribution.

The modern sloths are arboreal creatures of moderate size; they feed upon the succulent stems and leaves of tropical trees. By means of their curved claws, they hook themselves through the tangle of branches in the forest jungle. They are almost incapable of locomotion on the ground and when by accident they fall, they move about in a most awkward fashion in regaining their haunts.

The modern armadillo is a burrowing animal chiefly active at night. Its covering of segmented shelly pieces gives it more the appearance of a

reptile than of a mammal, but its warm blood, its mammary glands, and the hair that projects outward between the segments of its shell proclaim it a true mammal.

Modern sloths and armadillos are limited to the new world particularly to South and Central America though the armadillos extend northward through Mexico into the southern borders of the United States. None of these forms occur in the old world or in fact elsewhere than in the region just described.

Fossil sloths and armadillos are known in considerable numbers. Some of these are of huge size. Fossil ground sloths have been discovered whose skeletons justify the belief that the living animal must have been as large as a rhinoceros. Armadillo-like animals, the glyptodons, have been found whose skeletons are almost as

large as those of oxen. The fossil remains of all these sloths and armadillos are found exclusively in the new world and in that part south of the central United States. It is a remarkable fact that, notwithstanding the great difference between these fossil sloths and armadillos and their modern representatives, the living and the fossil forms should agree almost exactly in the regions where they occur. One is forced to conclude from facts of this kind, as well as from the circumstance, that most well-defined groups of modern animals, like the monotremes and the marsupials, occupy definitely restricted areas, that members of the same great group have had a common origin, for had they been specially created their distribution on the earth's surface would have called for no particular regularity.

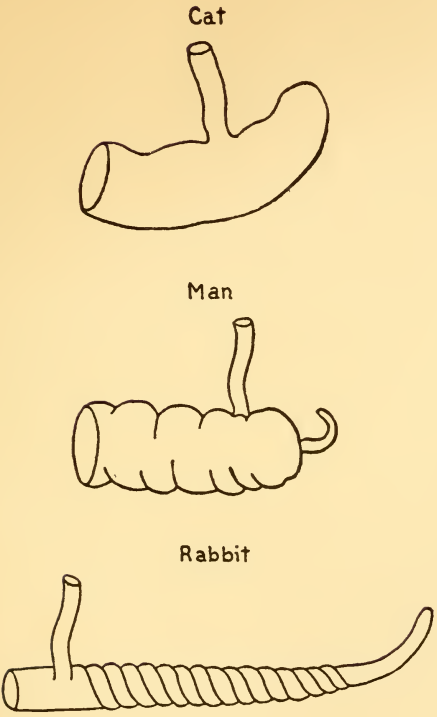
5. FROM RUDIMENTARY ORGANS

THE last biological topic to be considered in the present account as bearing on the problem of evolution has to do with rudimentary organs. Rudimentary organs are those organs that are without use or function. They are like the buttons on the sleeve of a man's coat; they are essentially useless and sometimes worse than useless. A well-known rudimentary organ, from the human body, is the vermiform appendix of the large intestine. This organ is a blind tube several inches in length and attached to the large intestine near its beginning. It is shown to the right in the figure on page 55. It is easily subject to inflammation and forms a danger center in the intestinal tract. In diseased states it is regularly removed by the

surgeon and even in normal conditions it is frequently excised as a precautionary measure. No one is known to suffer any inconvenience from its loss; in fact a person is commonly regarded as better off without it than with it. In consequence of its complete lack of function, it is a thoroughly good example of a rudimentary organ.

The condition of the vermiform appendix in man is by no means typical of this organ in other mammals. Cats show no sign of it, but in rabbits it is a highly developed structure and is intimately concerned in this animal with the regular activities of the large intestine.

Other rudimentary organs in man are easily pointed out. The external ear of the human being has attached to it three thin muscles, one above the ear, a second behind that organ, and a


Cat
Man
Rabbit

third in front of it. Most persons have no power of motion in these muscles and, in such instances, the muscles may be looked upon as purely rudimentary, but occasionally an individual will be found who can control them to a slight degree and who can thereby move his external ear. Even in such instances, however, the amount of motion is extremely slight compared with that seen in such animals as the horse and the dog, where the tube of the outer ear is directed with great freedom in a variety of ways and is used as a means of discovering the direction of sound. From the standpoint of actual usefulness, the three muscles attached to the human ear are quite as rudimentary as is the human vermiform appendix.

Well within the angle of the human eye next the nose is a slight fold of whitish membrane, the so-called plica

semilunaris. No use is known for this organ in man but in the cat, as one can readily see by direct inspection, in place of this fold there is a nictitating membrane, or third eyelid, which by its free movement back and forth across the eyeball serves as a means of protecting and cleansing that organ. The plica semilunaris in man is a completely useless remnant of this third eyelid.

In an enumeration of the rudimentary organs in man made some years ago by Wiedersheim approximately ninety such parts were noted. This seems like a considerable list for one species, but it is probably by no means exhaustive. Most higher animals, like man, abound in a great variety of such useless parts.

From the standpoint of special creation, it is by no means easy to explain the presence of such function-

less organs. If animals were specially created why should they contain scores of parts that are without use and that in some instances, like the vermiform appendix, are positively deleterious? A satisfactory answer to this question has never been given. From the standpoint of evolution, however, rudimentary organs are structures in process of disappearance, organs that are just dropping below the horizon of serviceableness. Their presence in a given form indicates that they were functional in some ancestor of that form, and that as evolution proceeded and the species changed, it dropped this particular part from the level of functional significance to that of uselessness. Such an explanation of the presence of these organs accords completely with what is known of them from all points of view.

6. CONCLUSION

We have now completed a brief survey of some of the more important fields of evidence concerning descent with modification. We have examined this question in the light of comparative anatomy, of embryology, of geology, of zoögeography, and of the study of rudimentary organs. In none of these aspects of the problem has there appeared reason for assuming that special creation has been the method by which the diversity of plants and of animals at present on the globe has been produced and in all of them there has been shown either strong evidence in favor of descent with modification or a state of affairs open to ready interpretation from this standpoint.

The several lines of evidence that have been considered in this connec-

tion could scarcely be said to have been available in the time of Lamarck, for most of them have been the result of the scientific endeavor of the last hundred years. It is therefore not surprising that in his day evolution received a serious setback, for at that time not enough was known to give the question a fair hearing.

Even when Darwin wrote, knowledge on many important points was very incomplete compared with what it is to-day. It is, however, a significant fact that practically all the lines of evidence cited by Darwin as confirmatory of evolution are significant to-day and much more extensively supported than they were in his time. The confirmation thus received is the result of the discovery and impartial accumulation of new facts on lines that bear on the question at hand. If to the naturalist of Darwin's time

the evidence in favor of evolution seemed persuasive, that which can be brought forward now would have been overpowering. It is this strength of the modern position that has placed every biologist of any standing whatsoever on the side of evolution. In other words, practically all biologists to-day accept without any reservations descent with modification as a process of nature. They no longer question this view. This statement cannot be emphasized too strongly.

At the same time that these biologists accept descent with modification as an actual occurrence in nature, they are most skeptical and reserved about what may be called the driving force behind descent. What is there in nature that has kept in motion this incredible capacity to produce new species? How is it that from age to age large and ever larger floods of

new forms have burst forth? To this question no biologist has a clear and unequivocal answer. It is this uncertainty that has been seized upon by a few thoughtless critics who have attempted to discredit in the eyes of the general public the well established fact of descent with modification by confusing it with the explanations of descent. This confusion, commonly due to ignorance, is the source of most of the contentions now met with in evolutionary controversies. It does not characterize the clear thinker. Because biologists have not as yet discovered how evolution takes place is no reason for denying evolution itself.

The explanations of the evolutionary process thus far offered are large in number. They include, to mention only some of the most important, Lamarck's hypothesis, Darwin's natural selection, Naegeli's idioplasmic

hypothesis, Eimer's orthogenesis, De Vries's mutation theory and the like. In so brief a survey as this volume offers it will be profitable to consider only the more noteworthy of these views and in conformity with this plan the next chapter will contain brief critical accounts of Lamarck's hypothesis, of Darwinism or the theory of natural selection, and of the mutation theory of De Vries.

IV

FACTORS IN EVOLUTION

FACTORS IN EVOLUTION

1. PREFATORY

In the early discussions on evolution it soon became apparent that, compared with the biblical account of creation, descent with modification required a relatively enormous length of time. This contrast between the two views was used by Cuvier in his opposition to Lamarck. Cuvier had careful measurements made of the skeletons of mummified Egyptian animals and of their recent representatives. No significant differences could be detected on comparing these two sets of measurements and Cuvier, therefore, concluded that if no measureable changes had overtaken animals in the three thousand years that separated the mummified from the modern forms, it was useless to con-

sider the possibilities of a process which, if it occurred at all, was almost inconceivably slow. Although Cuvier has since been shown to be wrong in his general deductions, the results of such speculations as this led transformists in the early days to assume a very long period for the evolution of life on the earth, a conception quite in line with the growing uniformitarian geology of the day. The assumption of a relatively great age for the earth and its inhabitants has been entirely justified by subsequent scientific inquiry, but in the days of Cuvier and Lamarck and even in the time of Darwin it was based on much less convincing evidence than at present. To-day it is beyond dispute that the age of the earth as the abode of life is to be reckoned in hundreds if not thousands of millions of years.

In consequence of these growing

opinions, there arose a belief among naturalists of the transformist school that evolution was so slow and gradual a process that no direct observation of it could ever be made. The life of man was not long enough to admit of even a glimpse at evolutionary change. This view was current in Darwin's day and prevailed more or less to the end of the nineteenth century. It served as a most unfortunate deterrent to scientific research, for it discouraged investigators from attempting any direct study of a process whose operations seemed to be so infinitely slow.

With the advent of the twentieth century a new phase in evolutionary investigation appeared. Through the work of Tschermak, of Correns, and particularly of De Vries the subject passed from the observational and speculative stage to the experimental

one, and instead of looking upon evolution as a process so slow as to be imperceptible, it was soon believed, as a result of experimental test, to be relatively rapid at least in particular instances. In fact it was declared that species might be created almost over night. Such a radical change of view had a profound effect on the growth of the subject and though the new programme may not have realized all that was expected of it, it brought the science into a vastly more wholesome state and led to positive growth of a most encouraging kind. In this revival of activity all the older explanations of evolution were brought to the test with the result that such ideas as Eimer's orthogenesis, in which variation was supposed to occur in definite and predetermined directions, and Naegeli's idioplasm theory, in which an internal perfect-

ing principle was assumed, lost ground and the field was left almost exclusively to Lamarckism, Darwinism and the mutation theory. A consideration of these views will now follow.

2. LAMARCKISM

LAMARCK's hypothesis as to the means by which evolution has been accomplished is best stated in his "Philosophie Zoologique" published in 1809, a year which is noteworthy as the birth year of Charles Darwin. Lamarck's explanatory views excited very little attention at the time of their publication, for, so far as the scientific world took any interest in evolution at all, it was concerned with the question of the validity of this doctrine rather than with its explanation. Fifty years later when Darwin advanced natural selection the explanatory aspects of this question came much more to the front. Then a contrast between Darwin's views and Lamarck's views could be drawn.

The explanation offered by Lamarck turned chiefly on the effect upon organisms of the surroundings or environment. Lamarck noted that marsh plants, such as the aquatic Ranunculus, which grew partly submerged and partly out of water, had leaves of different shapes in the two situations. Under water the leaves were finely divided, but in the air they were simply lobed. This difference he rightly conceived to be due to the environment, one situation producing the first type of leaf and the other the second. He looked upon this as a direct effect of the surroundings and regarded it of great importance particularly with plants. A special plant being thus directly dependent upon its surroundings for its peculiar form, any change in these surroundings would be likely to be followed by a change in the form of the plant, that is, an-

other form would arise and evolution could be said to have taken place.

Lamarck conceived the effect of environmental change on animals to be carried out in a rather more complex way than on plants. He illustrated this by several examples such as the webbed foot of water birds and the long neck of the giraffe.

Lamarck rightly believed that land birds were the ancestors of water birds, and in thinking of the transition, he pictured land birds coming more and more to frequent the shore, to pass much of their time in shallow water and to seek their food there. Such newcomers would from time to time get into deep water and naturally attempt to propel themselves by kicking with their legs. The muscular exercise of kicking would induce an extra flow of blood to the legs whose bones, muscles, skin, and the like

would respond by extra growth. In this way the skin between the toes would become firmer, tougher, and more extensively developed. These effects would be increased in the descendent stock, and as they accumulated generation after generation, the passage would be accomplished from the webless foot of the land bird to the webbed foot of the water bird.

Lamarck conceived that the giraffe's neck, to take another of his examples, was lengthened by a similar process. These animals were supposed to browse among the branches of trees. In their endeavors to reach the leafy food, they would naturally exert the muscles of the neck and this activity would induce an extra flow of blood to that region. In consequence the muscles, bones, and other parts of the neck would increase in size, just

as the arm of a man increases under exercise. As a result of this activity continued through generation after generation, the neck of the giraffe would lengthen and eventually reach the extreme condition seen to-day.

Both these instances involve a process more complex than that in the partly submerged plant, but in both of them the environment is the fundamental factor. With the bird the change from inland surroundings to a shore environment is the important element, and with the giraffe the change from a region where browsing was low to one where it was among trees. Thus as with the plant, environmental differences play the chief part in the evolution of these animals. Put briefly, the Lamarckian scheme, as applied to animals, is as follows: a change in the environment is followed by a change in habit, and a

change in habit is followed by a change in structure. Thus the condition of the animal is modified and evolution is the result.

Such an application of the Lamarckian principle, as is involved in the last two examples, requires what may be called the indirect influence of the environment in contrast with the direct influence as seen in most plants, but in both direct and indirect influences, the environment and its changes are the paramount elements.

In addition to the general principle that has just been illustrated, Lamarck also called attention to certain subordinate principles that he believed to be significant in evolution. First of these was the principle of use and disuse. Organs that are exercised tend to increase in size, and organs that are not exercised tend to shrink. This is so obvious a matter in every-

day life that it needs no special illustration and no one denies it.

Another principle that Lamarck advanced was the principle of effort, that in order to accomplish an end an animal must make an effort, must exert itself. If it did not so do its effective powers would diminish. This is an element of a psychological nature; it has a certain vague and intangible side not involved in the principle of use and disuse, for instance. It nevertheless plays no unimportant part in Lamarck's general hypothesis.

The scheme advanced by Lamarck, and briefly outlined in the preceding paragraphs, carries with it the impression of great naturalness. Everyone knows that activity or lack of activity modifies an organ and, granting that the changes thus produced are handed on generation after gen-

eration and emphasized, evolution seems to be a natural consequence. Is not this precisely the method by which plants and animals are moulded to their surroundings; is not this, in other words, the driving force that lies behind evolution? On the surface it seems as though Lamarck's hypothesis must indeed offer the true explanation.

3. LAMARCKISM CRITICIZED

NOTWITHSTANDING the ease with which Lamarckism appears to provide the necessary machinery for the evolutionary process, this hypothesis is not free from serious defects. Darwin considered it as a possible factor in evolution but did not lay much stress upon it. It was not until after Darwin's time that Lamarckism came into prominence in consequence of the contrast between it and natural selection. Half a century ago a new school, chiefly paleontological, arose which, under the name of neo-Lamarckian, attempted to establish and expand the principles of Lamarck. This school was opposed by the neo-Darwinians who, under the leadership of Weismann, made a vigorous onslaught against Lamarckism and

claimed natural selection as the all-sufficient factor in evolution.

The objections that were raised against Lamarckism by its opponents were first of all as to its limitations. As a process effective in evolution it applies to those changes that are induced either directly by the environment or indirectly through exercise, lack of exercise, and the like.

Some conditions seen in organisms do not easily fall under any of these heads. The protective coloration of insects is an example of this kind. Many insects exhibit colors, forms, and activities that make them easily mistaken for other objects in their environment. Moths resemble the bark of the trees on which they rest, butterflies, on closing their wings, become indistinguishable from leaves or the earth and the walking-stick insect gets its name from its resem-

blance to twigs. Anyone who has taken the trouble to acquaint himself with examples of this kind must have been struck with the perfection of the resemblances and with the evident protection that the creature enjoys through being mistaken by its foes for something other than it is. It was this principle that toward the end of the Great War led to the camouflaging of vessels, of artillery, and even of men. The insects that are camouflaged do not acquire this state through individual activity, but are hatched out in this condition. They receive their protective markings fully formed, in the nature of birthrights as it were, and no efforts on their part make the camouflage more or less complete. In this respect, the insects are quite unlike the fishes, the frogs and toads, and especially the chameleons where the colors of the

skin are under nervous control, with the result, that the animals can momentarily change colors and patterns and thus, so to speak, exercise this system as muscles may be exercised. In the insect the condition is fixed once for all and the individual is incapable of modifying it. Fixed conditions of this kind are beyond the reach of the Lamarckian principles and form a body of material the evolutionary explanation of which must be sought for in other directions. Thus, granting the validity of Lamarck's hypothesis, it, nevertheless, falls short of an explanation of all the evolutionary aspects of organic nature and must be supplemented by other factors to reach completion.

But not only does Lamarckism fail to apply to all classes of instances under organic evolution, it also involves, as one of its essentials, the

assumption of the inheritance of acquired characters. Acquired characters are those peculiarities that are gained during the lifetime of an individual as contrasted with his inborn traits. That Lamarckism shall be effective, it is necessary that precisely these characters be inherited. For a long time biologists have attempted to show that such characters are inherited, but thus far they have been unable to get any conclusive evidence that such is the case.

The chief opponent of the inheritance of acquired characters was Weismann (1834–1914) who pointed out that the bodies of the higher animals were composed of two categories of cells, the body cells proper such as muscle cells, nerve cells, skin cells, and the like, and the reproductive cells, the egg cells and sperm cells. He also showed that acquired

characters were changes in the body cells — muscle, nerve, skin and so forth — and that there was no known mechanism whereby the changes registered in these cells could be transferred to the reproductive cells in order that such changes might be handed on to the offspring. If a blacksmith through exercise increases the muscles of his arm, how are these muscles to modify his reproductive cells that his offspring may have larger arm muscles than they otherwise would have had? This theoretic objection to the inheritance of acquired characters seems to many to be an insuperable one. It is, however, an objection based on ignorance and may at any time be set aside by new discovery.

Many of the older advocates of the neo-Lamarckian school pointed to the inheritance of mutilations as evidence in favor of Lamarck's views, and it

was this that led Weismann and others to experiment in this direction. Colonies of mice and of rats were subjected to mutilation and were then used for breeding with the view of ascertaining whether such mutilations were heritable. Thus the lengths of the tails of a number of adult white mice were measured, their tails were then cut off, and they were used as breeding individuals for a new generation. When the second generation had matured, their tails were in turn measured and cut off and a third generation was produced from them. After the breeding of approximately twenty such generations, all of which had been subjected to the amputation of the tails at an appropriate stage, the tails in the final generation were found to be as long as those in the first generation. Such mutilations, then, gave no evidence

of being inherited and this conclusion was to have been expected at the outset, for it is well known that the innumerable deformations of the human body as practiced by primitive races whereby the ears, the lips, the nose, and even the head become misshapen, have had no inborn effect upon the stocks concerned. The ancient religious rite of circumcision, though practiced for very many generations by the Hebrews, has had no effect in shortening the foreskin of Hebrew male infants. If mutilations were inherited man would be a mere fragment of what he is as a result of handing on from one generation to another the injuries received from wars and accidents. Mutilations evidently are not inherited and the so-called examples of this kind seem to be nothing but old-wives tales or coincidences.

But even though mutilations have no effective influence on the germ cells of the animals suffering from such defects, may not bodily activities, more normal in character than mutilations, influence the germinal elements? May not a normal but novel and unusual condition of the body cells influence the contained germ cells? To test this Castle and Phillips attempted the very ingenious experiment of transferring germ cells from one individual, with a given set of bodily traits, to another individual, with very different traits, and of testing the results of such a transfer by breeding. They proceeded in the following way. The ovaries were removed from a young guinea pig of pure white stock and in their place were set the ovaries from a pure black individual. After recovery from the operation, this white female

with "black" ovaries was paired with a pure white male with the result that between six to twelve months after the operation she bore two litters of young. These consisted in all of six offspring every one of which was black exactly as though a black female had been paired with the white male. This test shows that after almost a year of residence in the foster white body the ovaries from the black female still retained in full force their original potentialities and gave no evidence that the new foster body had influenced them in the least. This experiment supports Weismann's contention that the germ cells are essentially independent of the body in which they reside.

But again it may be maintained that the period over which such trials extended was much too short for a real test of the question and that, if

experiments could be devised that would of necessity last over a number of generations, results of a very different kind might be obtained.

To try out this aspect of the problem numerous investigations have been made or are still in progress. Few workers have done more in this direction than the Viennese experimentalist, Kammerer. Of his numerous studies one may be chosen as an example. The European spotted salamander deposits either numerous eggs or young that have been hatched in the mother's body in ponds and pools in damp woods. All the young, irrespective of their condition of birth, are provided with gills and live for several months in the water after which they lose their gills and become inhabitants of the land. The European black salamander gives birth only to active young, usually

two in number, and these are born without gills and in full readiness for terrestrial life. By keeping the spotted salamander away from water, Kammerer attempted to change its breeding habits in the direction of those of the black salamander. Such artificially restrained salamanders retained their young in their bodies till the young had lost their gills and were in a condition for life on the land. The young of such parents were reduced in number, as compared with the normal number produced, and were mostly black. In both these respects the stock approached the European black salamander. Spotted salamanders, whose parents had thus been modified in habit by experimental conditions, on arriving at sexual maturity were, during their breeding season, given access to water. They deposited their young in the water at

an advanced stage of growth, and these young remained in the water only a few days instead of several months. Thus the reproductive habits of the spotted salamander, by a change in the environment, were modified in the direction of the black salamander, and this modification persisted more or less in their descendants, even after these descendants had been allowed to return to the original environment.

Several lines of experimentation such as the one described in the preceding paragraph have been carried out by Kammerer within the last few years and point to the inheritance of acquired characters. How sound the experimental evidence is in all such cases remains to be seen. Is it not possible that the peculiarities that Kammerer believed he originated in the spotted salamander, to take this

as an instance, may have been inborn traits in this animal which were simply called into evidence by the changed environment rather than produced by it? Certainly such aspects of the problem should be tested before a final conclusion can be arrived at, and in so crucial an experiment as the one described, it is extremely desirable that independent evidence on the same point from other investigators should be at hand before a final decision is reached.

Other students of this general problem have also carried out extended series of experimental studies reaching over many generations. Thus the Americans Guyer and Smith have advanced evidence to show that eye defects produced in one generation of rabbits are inherited by the descendent stock. But here the defects produced and those as-

sumed to be inherited are often quite different and the question, therefore, of real inheritance remains open. The same general criticism applies to Griffith's studies on the inheritance of defects in the internal ear of the rat. Both these lines of investigation, and especially those of Guyer and Smith, are, however, extremely near the point and are very suggestive.

A novel and very remarkable test of the inheritance of acquired characters is one that has been advanced by the celebrated Russian physiologist Pawlow. It is well known that mice can be trained easily to come to a particular place for food. If, during this training, a bell is sounded each time that the animals are fed, they will learn after a while to come for food at the sound of the bell even when no other signal for the presence

of the food is given. This kind of response where a second form of stimulus, such as the sound of a bell, replaces the primary stimulus is called by Pawlow a conditioned reflex. To induce this state in untrained mice required, according to him about 300 lessons. The descendants of this trained stock, however, acquired this capacity after only 100 lessons, the third generation after 30 lessons, the fourth after 10, and the fifth after 5 lessons. Pawlow expressed the hope that in time a generation of mice might be produced in which this conditioned reflex would occur immediately and, so far as that generation itself was concerned, without training at all. These statements were published in a preliminary way in 1923 and, though in certain respects they are very precise and final, it is hardly possible to comment on them

till the complete report is published. They are nevertheless full of significance.

The whole problem of the inheritance of acquired characters has arrived at a stage where the results are coming to be of the first importance, and it must be admitted even by those who oppose Lamarckism that the recent tests have come much nearer yielding conclusive results than those attempted in the early stages of the controversy. Nevertheless it is generally agreed by almost everyone concerned that up to the present time no entirely convincing instance of the inheritance of acquired characters has come to light and that from this standpoint Lamarckism must be admitted to be without direct support. There are, however, those like Samuel Butler and, more recently, George Bernard Shaw, as disclosed in his

preface in "Back to Methuselah," who cry out for Lamarckism, but their cry is far-fetched and although the Lamarckian doctrine may eventually prove true, the proof of it will come from other sources than literary intuition.

The conclusion that Lamarckism is a possible but unproved factor in evolution is a statement that represents, I believe, the opinion of the majority of modern biologists. That the criticism upon which this statement rests applies to animals only in so far as they exhibit sexual reproduction is, I suspect, generally appreciated though not so commonly stated. In organisms that reproduce in this way, as Weismann clearly showed, the cells that make up the creature are divisible into the two classes of body cells and reproductive cells and, as already noted, it is extremely difficult, if not

impossible, to show how under such circumstances the inheritance of acquired characters can take place. In those forms in which non-sexual reproduction is found the inheritance of acquired characters must be a regular occurrence, for, in this method of reproduction, the whole body of the organism divides into two or more masses, and the body cells of the parent, with all the peculiarities that the environment may have impressed upon them, become the body cells of the offspring. Here the method of reproduction is as clearly in favor of the inheritance of acquired traits as in the other instance it is opposed to this process. It must be kept in mind, however, that non-sexual reproduction is a characteristic of the plants and the lower animals and is absent from the higher forms. It occurs on the animal side

among protozoans, sponges, corals, starfish, moss-animals, worms, and the group of sea-squirts or tunicates, but it is not known among snails, clams, crustaceans, insects, or the vertebrates. If, therefore, the inheritance of acquired characters is a feature of non-sexual reproduction and the Lamarckian principles may apply where this occurs, it is after all a limited application and illustrates again what has already been pointed out that Lamarckism at best cannot be regarded as an all-inclusive factor in evolution. From what has been said it appears to be at best a possible element in this process.

4. DARWINISM

DARWINISM, or as it is often called natural selection, is an explanation of evolution that originated independently in the minds of Darwin and of Wallace. It is best stated in Darwin's memorable work "The Origin of Species" (1859), without doubt the most significant single publication of the nineteenth century. As a result of the discussion called forth by the appearance of this work, two great steps in the progress of biology were accomplished; first, the acceptance of descent with modification, instead of special creation as the order of organic nature, and, secondly, the establishment of natural selection as a driving force in evolution. The first of these has already

been taken up; the second remains to be considered.

In seeking a clue as to the way in which evolution takes place Darwin first turned his attention to plant and animal breeding. Domesticated plants and animals, notwithstanding their great diversity and variety, are the products of comparatively few wild species. Thus all the various races of domesticated pigeons have descended from the European rock-pigeon. The original wild stock of this bird is fairly well represented by the common domesticated individuals of slaty color, with two dark bars on the wings and with a white rump. In addition to this stock there are over 150 named varieties of pigeons that breed true. These include such unusual forms as pouters, carriers, fantails, tumblers, jacobins, trumpeters, and a host of others whose forms and

habits are most diverse. Were these met with in nature, the zoölogist would unhesitatingly assign many of them to separate species or even distinct genera. What is true of pigeons is also true of other domesticated animals such as dogs, horses, swine, cattle, and the like.

In considering evolution Darwin first set for himself the task of accounting for the origin of domesticated stocks. He found that when the breeder wished to develop a particular feature, such as an excessive covering of feathers on the leg and foot of a pigeon, he watched his stock closely and chose for breeding purposes those individuals that showed evidences of the trait he sought. By this method of selection applied to one generation after another, he gradually arrived at a stock in which the given feature was as pronounced

as he wished and thus attained his end. Darwin called this process artificial selection and believed it to be the method by which man had produced from comparatively few wild sources the great variety of domesticated forms with which he was surrounded.

Darwin then raised the question, Is there not a similar process going on in nature as a means of producing the limitless variety of life in the open? This he believed to be so and, in contrast with artificial selection, he designated this process as natural selection. The grounds for his belief in natural selection as an actual process in nature may be briefly stated in the following way.

More organisms are produced than can possibly continue to exist because of the limitations of food, space, and other essentials. This comes about

from the fact that each individual or pair of individuals gives rise to several offspring and often to many. It is not always appreciated what this method of increase means.

If a single plant produces at the end of its life two seeds and these grow to mature plants the next year and produce each two seeds and so on, in the twenty-first year the original plant will be represented by over a million descendants. Even an animal, such as the elephant which breeds with extreme slowness, will nevertheless in time populate the globe, if all its progeny live and reproduce. When rapidly reproducing forms such as the insects are considered, the increase in numbers is bound to be quickly prodigious so that the swarms of locusts described in the past seem as nothing to what might have happened. All organisms

are endowed with such powers of increase that even the slowest would in time overrun the earth.

Darwin further recognized the fact that the offspring of all animals and plants are more or less diverse, and that no two are ever exactly alike. This is apparent to everyone. In a litter of puppies the individuals are quickly and easily distinguished by size, markings, vigor, disposition, and the like, and we name them and treat them as we do separate persons.

These slight individual differences are, according to Darwin, either favorable or unfavorable for the continued life of the given organism and, since more individuals come into the world than can possibly survive, those with unfavorable traits are less likely to reach maturity and leave offspring than those with favorable traits. In this way there is a continual elimi-

nation of the less fit with the result that the fittest survive, leave offspring, and thus hand on to future generations their peculiar qualities, for the individual differences noted by Darwin are the inborn traits of each individual. Thus a form of natural selection is continually in operation ever moulding plants and animals with great nicety to their fluctuating surroundings. This, according to Darwin, is the mainspring that keeps evolution continually moving.

Survival of the fittest, struggle for existence, and other like expressions have been used as figures of speech with which to make clear what is meant by natural selection. And these expressions do indicate what at times occurs in nature, but anyone who looks upon the world of plant and animal life will not see a field of battle, an arena of combat, with each

living thing ranged against its neighbor. In fact when we seek a figurative expression for peace and quiet, we are very likely to turn to that very nature which, according to these phrases, should be in deadly turmoil. Nevertheless, natural selection is probably running at full speed in every quiet countryside. Four seeds from a given plant fall on a small plot of ground. All germinate and produce growing plants, one a little in advance of the other three. The early one shades the others, reaches maturity first and sets its seeds. Autumn comes and the other three have not yet flowered and in consequence they fail to produce fruit. Natural selection has taken place. The early plant leaves offspring for the next year; the other three are unrepresented. All may have lived what is essentially the same length of time

and all in perfect peace; there has been no struggle, no conflict, but natural selection has nevertheless occurred. The essential act of reproduction has been completed by only one and that one has thereby handed on its inborn peculiarities to the next generation. The same operation is true of animals. Any creature that fails to leave offspring suffers elimination from the standpoint of natural selection, yet such an animal or plant may live individually as long or even longer than many another whose progeny will reach into future generations. Hence natural selection is not necessarily concerned with the destruction of the individual, as is often inferred by the figurative expressions already alluded to, but is a process that has to do with the way in which plants and animals succeed or fail in leaving off-

spring. In most instances it is a quiet, unobtrusive natural phenomenon that permeates nature in every direction and is more truthfully represented by the quiet countryside than by the turmoil of battle.

Having reached some idea of what is meant by natural selection or Darwinism and having seen how it may be an active force in moulding plants and animals, we may pause a moment to compare it with what Lamarck believed to be the energizing factor in evolution. Natural selection first of all does not suffer from limitations to the extent that Lamarckism does. Natural selection not only applies to all that Lamarckism reaches but it meets with success such conditions as the protective coloration of insects, which, it will be remembered, were hardly within the range of Lamarck's principle. Insects, that have only an

imperfect resemblance to the bark of the tree on which they rest, are much more likely to be espied and carried off as prey, than those that have a closer resemblance. Natural selection may in this case be expected to act with full efficiency whereas Lamarck's principle, as already indicated, is apparently entirely inapplicable. From this standpoint, natural selection is not subject to the limitations that characterize Lamarck's hypothesis.

Further, natural selection is not concerned with the inheritance of acquired characters. The slight individual differences, upon which it is believed to act, are not differences due to the action of the environment on the given organism but are inborn traits which in consequence may be handed on through the germ cells to descendent offspring. In these two

particulars natural selection has a great advantage over Lamarckism. It is of wider application and it avoids the difficulty concerning the inheritance of acquired characters.

It may not be amiss if at this point we compare Lamarckism and Darwinism by attempting to show how each may be made to apply to the same example, and as an instance to to be so treated, we may take the webbed foot of the water fowl originally discussed by Lamarck. According to his hypothesis this structure arose by the accumulation, in the course of generations, of acquired modifications which resulted from a change of habit in consequence of the bird's removal from purely terrestrial surroundings to an aquatic environment. From Darwin's standpoint the webbed foot resulted from selection, among a diverse offspring, whereby

those with favorable inborn traits would be preserved and have offspring as contrasted with those whose conditions were less favorable. Thus Lamarckism deals with difference induced by the environment, acquired characters, and Darwinism with inborn native differences.

Before leaving this comparison of the two views it should be pointed out that they are in no sense mutually exclusive. It is sometimes implied that if Darwinism could be shown to be true Lamarckism must be false and vice versa. It must be evident, however, that such is not the case. There is not the least reason to assume that one view is in any way incompatible with the other. It is entirely possible that both Lamarckism and Darwinism may be acting at once and in perfect accord as mutually efficient factors in evolution.

5. DARWINISM CRITICIZED

In discussing Darwinism or natural selection from a critical standpoint we may begin by inquiring whether there is any evidence that this process is an actual occurrence in nature. To answer such a question, one would naturally turn to conditions where organisms are subjected to severe and unusual strain. Some years ago Bumpus studied the effects of a severe winter storm on sparrows. As a result of a heavy sleet many birds were brought close to death. A large number of these spent birds were collected, and of the total collection, 64 died and 72 revived. Do the members of these two groups thus naturally established differ, or are they essentially the same? A statistical study of the two sets of

birds showed that the survivors were less variable than those that perished. The birds that died were, in many cases, extreme individuals. For instance, they more frequently had large bodies combined with small wings, or the reverse, than the survivors had. Hence they represented conditions in which it might be said that there was too much power or too little power for the wing surface and the like. This disadvantageous tendency was in general the cause of their death. One may therefore conclude that, under the severe circumstances mentioned, elimination was not haphazard but rather, as would be expected, that the least fitted birds succumbed and the best fitted survived. In this rather crude way, evidence of a selective capacity in nature has been obtained, and from instances of this kind, it is fair to conclude that

natural selection is a process that is in actual operation in the world about us.

Natural selection, however, is not without its limitations. It is an operation that at best can lift organisms only to the level of positive needs. Nature, with a certain prodigality, often goes much beyond this limit. Examples are abundant enough. Many crustaceans have the curious habit of casting injured legs and other appendages. When a crab loses a part of one of its legs, it recovers by a new growth, but this new growth does not replace simply the lost part; the old stump is thrown off from a so-called casting joint at the base of the leg and a wholly new leg is formed. Most crabs, picked up on the shore at random, are undergoing this process on some one of their numerous appendages.

Hermit crabs live with the pos-

terior parts of their bodies tucked away in some dead snail-shell appropriated by the crab for this purpose. Their hind appendages are therefore protected and, according to Morgan, who recorded this case, these appendages are never found suffering from injury as their front legs are. Nevertheless, if by experimental steps the hind appendages are injured, they are cast and recovered as the exposed appendages are. Here then is an instance where nature has stepped beyond the actually necessary, and where it would be difficult to offer for the condition an explanation based purely upon natural selection.

Another instance of the same kind occurs among certain almost microscopic crustaceans, the copepods. These small creatures are abundantly represented in the surface waters of the sea. Copepods of different sexes are, as

a rule, strikingly unlike. The females are relatively inconspicuous and simple in their dress. The males, on the other hand, are gaudy and ornamental in the extreme. In their colors they are veritable microscopic peacocks. In fact the comparison with birds is quite appropriate, for just as the male bird often has a conspicuous plumage so is the male copepod commonly highly decked out, and one would suppose for the same reason, namely, to attract the females at the breeding time. But the female copepod, unlike the female bird, has eyes that are quite incapable of taking in all this beauty, and we meet again a condition in which nature seems to have gone so far in excess of what is necessary that natural selection cannot be offered as a means of explaining the condition. This kind of excess, which is an example of what has been

called hypertely, is a common occurrence in nature and is beyond the reach of natural selection.

The most serious objection that has been raised against natural selection is its apparent inability to launch any real change. When we consider how very slight and insignificant the individual differences are in any group of plants or of animals, it is almost inconceivable that these differences can afford sufficient grip for what natural selection is supposed to do in producing a new species. Once well established, it is easy to see how a new and advantageous trait can be fostered and developed by this process, but at the inception, it would seem impossible that natural selection could start a new feature forward from such small beginnings. Individual differences are not sufficiently life and death differences to enable

natural selection to obtain an initial hold. From the time of Darwin this has been the great obstacle to his theory, and no Darwinist has thus far successfully met this objection.

When we view the face of organic nature, we see such an array of marvelous adaptations and such a bewilderment of plant and animal species, many of which are separated one from another by differences of a very slight kind, that we are forced to admit that it is inconceivable that natural selection, as understood by Darwin at least, could have produced what is before us. This conviction has so impressed itself upon the minds of most modern evolutionists, that they have one by one come to the conclusion that natural selection, which in Weismann's time was declared to be all-sufficient in evolution, may after all be of little real significance.

Opinions of this kind have been frankly expressed by such eminent authorities as Bateson in England and Morgan in America, and they reflect the view of the majority of biologists the world over.

Although the statements of these, and other authorities on this subject, have been made with perfect clearness and in full knowledge of what the words imply, they have been seized upon by many thoughtless persons as evidence that biologists are abandoning the doctrine of evolution. What is really meant by these declarations, as must be evident to anyone who has read thus far, is that descent with modification, or evolution, is not questioned, but that the particular explanation of it, known as natural selection, or Darwinism, is seriously doubted. One often sees in current literature lists of noted biolo-

gists who are said by anti-evolutionists to be opposed to evolution, but, when the ground for these statements is scrutinized, it is commonly found that the authority named questions natural selection (Darwinism), but not descent with modification, or evolution, in the ordinary sense of the word. In a recent newspaper a prominent Boston pastor names "some scientists who at least call in question the loudly asserted proof of evolution." These names include those of J. P. Lotsy and William Emerson Ritter both of whom have criticized Darwinism but, to the best of my knowledge, are firm believers in evolution. If by Paul Kamerer is meant Paul Kammerer and by E. B. McBride, E. W. McBride, the same statement applies to these zoölogists as to the other two scholars named. Hence this list includes several well

reputed evolutionists. The confusion whereby these names have been included has probably arisen through failure to distinguish Darwinism from evolution. It is unclear thinking of this kind that is responsible for many of the present contentions.

In the opening portion of this section, it was pointed out that natural selection was without doubt a real occurrence in nature, and as the discussion progressed, it was made clear that this process, at least as understood by Darwin, fell short, and perhaps far short, of accomplishing what it was originally believed to do. This, in general, seems to be the modern opinion concerning it. That it is a real factor in evolution, there is not the least doubt; but that it is a subordinate factor, and perhaps even a very subordinate one, is likewise true. Biologists know that one spe-

cies comes from another, but how this is accomplished no one apparently can yet explain. As a contributing factor, natural selection doubtless had a hand in this operation, but it is in the rough-hewing of the species, and not in the polishing of the final product that it is concerned. The polishing, which after all is perhaps the most essential aspect of the process, seems still to be hidden from scientific gaze.

6. THE MUTATION THEORY

For almost forty years after the promulgation of natural selection, biologists were content to speculate on the way in which plants and animals might be changed through this principle. Only as the methods of zoology and of botany changed, from the more purely observational to the experimental, did evolutionary investigation receive a new impulse. This change in evolutionary work may be said to have been initiated, about the beginning of the present century, in the studies on heredity, carried out more or less independently by Tschermak, by Correns, and especially by de Vries. One of the results of these studies was the unearthing of the long-neglected but highly important publications of Mendel which had

appeared some thirty years previously. The principles, contained in Mendel's writings, were at once made the basis of an extensive and thorough-going experimental programme and served, at the same time, as ground on which de Vries erected his mutation theory.

Those portions of Mendel's work that are directly concerned with the mutation theory are easily and quickly grasped. They can be illustrated by what occurs in animals as well as in plants. If we breed a pure black guinea pig to a pure white one, the offspring are always black and if these offspring are bred amongst themselves, they produce young one-fourth of which are pure white and three-fourths are black. On testing the black individuals, one-third of them, or one-fourth of the total, can be shown to be pure black and the

other two-thirds, or one-half of the total, can be shown to be mixed, in that, like their parents, they will when bred together produce both black individuals and white individuals. The remarkable feature of such breeding series is the regularity with which the proportions, just stated, occur. The occasion of these remarkable Mendelian proportions can be seen when such a series, as that described, is analyzed.

When opposing characters, such as white and black, are combined in breeding, as in the case of the guinea pigs mentioned in the preceding paragraph, only one of these characters appears in the first generation of offspring, namely, in the particular instance under consideration, black. All guinea pigs in the first generation after the cross white-black are black. But these black individuals carry

hidden in their bodies the white trait, for, when they are bred amongst themselves, one-fourth of their offspring are white. Black, then, in some way overcomes white; not that it obliterates the white, but it holds this trait in abeyance. In the language of the modern breeder black is said, in a case such as the guinea pig, to be dominant over white and white is said to be recessive to black. This state of affairs, though not universal, is common to many such pairs of breeding characters. As a generalization, it is often referred to as the principle of dominance and was one of the discoveries of Mendel.

A second and very much more important principle, that is illustrated by the example under consideration, is, what may be called, the principle of the purity of the germ. It is briefly this: a given germ cell, be it

sperm or egg, can carry the exciter or gene of only one of two opposing characters, such for instance as white and black. No germ cell can carry a gene for white and a gene for black at the same time. In any pair of opposing traits, the gene of only one can be present in any germ cell. In other words the germ cells are in this respect always individually pure.

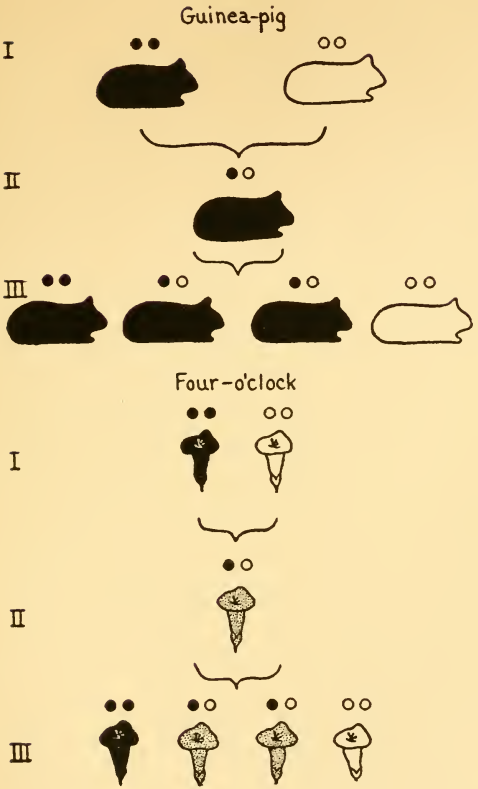
This principle of the purity of the germ cell makes clear the remarkable proportions, already pointed out, in the second generation of offspring. It will be recalled in the example of the guinea pigs that, in the second descendent generation, there were one-quarter or twenty-five per cent pure whites, another quarter or twenty-five per cent pure blacks, and a half or fifty per cent black individuals which, however, were really mixed, for, on being bred amongst them-

selves, they, like their parents, produced whites as well as blacks.

If, now, we examine the whole breeding series from the standpoint of the purity of the germ, we shall find reason for the occurrence of the proportions given. This can be done best by reference to the diagram on page 131. Here it will be seen that the source of the descendent stock is the pair of guinea pigs, one white and the other black, represented in outline at the top of the page. Which of the two is male and which female makes no difference so far as the final outcome is concerned. The white one is supposed to have been derived from a pure white stock, that is, from a stock which in all its pairings, within its own bounds, produced nothing but white individuals. Hence the white pig must be assumed to have come from an egg containing a

white gene, fertilized by a sperm also containing a white gene. This is represented in the diagram by the two white circles above the white pig, one for the egg and the other for the sperm. Such an individual can produce only one class of germ cells, namely those with white genes. Assuming in this particular instance that the white pig is the female, she may then be described as an individual producing eggs all of which carry the white gene. If the white member of the pair is the female, the black one must be the male and what has been said of the white pig may be said of her black mate, except that black gene is to be used in place of white gene and sperm cell in place of egg cell.

In the first descendent generation all offspring, in the present instance, would be the product of a white egg fertilized by a black sperm. This is


Guinea-pig
I
II
III
Four-o'clock
I
II
III

indicated by the white circle and the black circle in the diagram over the representative of this generation. In consequence of the dominance of black over white, all individuals, in this generation, will have black coats. But since they arise from a germinal mixture, each of these individuals will be able to produce two kinds of germ cells, the males white sperm and black sperm, and the females white eggs and black eggs. If, now, we assume that the two kinds of eggs are produced in equal numbers and that the same is true of the sperm and that the union of egg and of sperm is purely fortuitous, the kinds of guinea pigs and their proportionate numbers, as already stated for the second descendent generation, will be exactly realized. For with two kinds of sperms and two kinds of eggs, there will be four possible combinations in

fertilization. Once in four chances a white sperm will fertilize a white egg, a process which will yield the twenty-five per cent pure white guinea pigs. Once in four a black sperm will fertilize a black egg and thus will arise the twenty-five per cent pure black guinea pigs. Once in four a white sperm will fertilize a black egg and once in four a black sperm will fertilize a white egg and these two classes taken together will yield the fifty per cent mixed stock which, like their parents, can produce either white or black offspring. Thus the assumption of the purity of the germ leads to a simple and illuminating understanding of the proportionate numbers of young in the several Mendelian classes.

This assumption has been tested by geneticists in many ways and has been found to hold good. In fact, the

whole set of Mendelian principles has proved in the hands of the experimentalist little short of marvelous in their application. Exceptional cases often occur, but when these are worked out, they are commonly found to be in essential agreement with the general principles. Thus when the red-flowered variety of the common garden four o'clock is crossed with the white-flowered form, as shown on the lower half of page 131, the offspring are neither red-flowered nor white-flowered but have flowers of an intermediate tint, pink. If now these offspring are bred amongst themselves three classes result: twenty-five per cent pure whites, twenty-five per cent pure reds, and fifty per cent pinks, a state of affairs that may be described as parallel to that of the guinea pigs, so far at least as purity of the germ is concerned but without

dominance. In this way particular examples may show individual differences and thus illustrate the extent to which the general principles are open to readjustment.

De Vries, having discovered independently much that was afterwards found in the writings of Mendel and having come to many of the same conclusions that this writer had arrived at, turned to the problem of evolution in the hope that the new ideas on heredity would be helpful in understanding descent with modification. In 1901 he published the first general account of his mutation theory. According to this theory, the characters by which we distinguish different plants and animals are made up of units which are sharply separated from one another and are without intergrades. They are represented by such features as black and

white in the guinea pig's coat. These opposing traits were called unit or elementary characters by de Vries and, in describing them as elementary, he meant that they partook in their separateness of the nature of the chemical elements. Every organism is marked by a great array of these unit characters. In the guinea pig, for instance, there are coat colors, white, black, piebald and the like, differences in hair, long, short, rosetted, or smooth, and a host of other features all of which are inherited in accordance with Mendelian principles. Thus the pairs of traits in Mendelian inheritance are the unit characters of the mutation theory.

According to de Vries a real species, or as he called it an elementary species, is to be described from its unit characters and any new combination of unit characters is a new species. A

black guinea pig differs from a white guinea pig in one unit character, and yet this is sufficient to place these two individuals in different elementary species. This is certainly a novel conception, for it implies that two brothers may be of diverse species provided they show a unit character difference. In evolution, however, we are not so much concerned with this aspect of the subject as with another.

As already stated, the unit characters, by which elementary species may be distinguished, show no intergrades; they are fixed characters. Hence the difference between one elementary species and another is an abrupt difference. These abrupt differences are what de Vries calls mutations, and he contrasts them with the very slight individual differences which are seen between members of

the same species and which are commonly designated as variations. Variations, according to de Vries, are always very slight and insignificant. They never even approximate the magnitude of a mutation. Mutations on the other hand are striking differences such as black or white in the coat of a guinea pig and represent, in this sense, considerable jumps or breaks. Variations are like the slight movements that a cube may be made to execute when it is wabbled about on one of its faces. Mutations are like the changes that arise when the cube is turned from one face to another.

The mutation theory is to the effect that evolution takes place not through small differences or variations, as Darwin believed, but through large and sudden changes, mutations. Just as the cube does not progress when it

merely wabbles back and forth on one side, so evolution makes no progress through variations. Only when mutations occur, when the cube rolls over on to a new face, is evolution taking place. Darwin recognized mutations as conditions in nature and used for them the breeder's common name of sport. He was doubtful, however, whether they had any significance in evolution. To de Vries they are the only real factor in evolutionary progress.

No one can have bred plants or animals for any length of time without having noticed the frequency with which mutations occur. Morgan, in his exhaustive study of inheritance in the fruit fly, has recorded many scores of mutations, and there is no reason to suppose that they do not occur as frequently in open nature as in the laboratory.

Whether a mutation persists or not depends upon its nature. If it is in a favorable direction, the individual possessing it is likely to be preserved and find a mate. As such changes are handed down undiminished by Mendelian inheritance, the mutation would be expected to reappear in many of the descendants in full vigor. In this way, it could establish itself in the stock and help to modify that stock so as to form a new species. As de Vries rightly states, this process of preservation involves natural selection, for the retention of such a character depends upon this principle. All mutations must run the gantlet of natural selection. In this sense, the mutation theory and natural selection are mutually dependent. The mutation theory yields the grain for the natural selection hopper.

It must be evident that the muta-

tion theory presents a means of avoiding the chief difficulty with which Darwinian natural selection has to contend. That difficulty, it will be remembered, had to do with the first steps in the origin of favorable traits. These steps are not necessary in the origin of mutations, for mutations appear fully formed and are not built up by slow degrees. This is the great advantage that the mutation idea has over Darwin's view of the way in which new traits are supposed to be ushered in. As mutations they enter fully formed.

Difficulties with the mutation theory can be easily found. First of all this theory depends upon Mendelian inheritance and what that kind of inheritance implies as to the separateness of characters. But characters often blend, in fact there may be such a condition as blended in-

heritance, and such a condition, if at all general, would be very restricting to the mutation view.

Mutations further give the impression of laboratory and of garden products, rather than of products of the land and sea. Mutations certainly occur in nature, witness albino animals, but the experimental product seems to be far removed from what is demanded by open nature. Many workers have been so impressed with this aspect of the question, that they have come to look upon the great biological advance of the last two decades as illuminating, from the standpoint of heredity, but as having very little real bearing on the evolution problem. The truth is that the mutation idea, and all its intricate connections, are somewhat too novel to admit of final judgment.

What the factors of evolution are,

what the moving forces behind this great natural process are, no one is in a position to state. Lamarckism may be one of these. Darwinism alone, or supplemented by the mutation idea, seems quite clearly another though perhaps a subordinate one. Others still are probably to be discovered, for it is unlikely that a process so intricate, so many-sided, and so far-reaching as organic evolution should depend for its energizing on only one source.

V

HUMAN APPLICATIONS

HUMAN APPLICATIONS

MAN as an animal is a product of evolution and is subject to its laws as all other animals are. Such a statement, however, does not mean that man with all his complexities is at once understood the moment this position is assumed. The evolutionary standpoint, like a mountain top, is a commanding situation for a general survey, but it does not do away with the intricacies in the field of vision, it merely brings them into more truthful relations with the whole.

The derivation of civilized man from a primitive human stock is a subject that has grown so enormously, in the last few decades, that its treatment merits a volume. The new information on the subject, that has come to us since Darwin's time, is

simply overwhelming in amount. Man appears to have been on the earth for nearly half a million years. His oldest known representative is from Java, the Trinil man or Pithecanthropus, a restoration of whose head has been made by McGregor. This is shown in an outline sketch at the top of page 149. For the use of this sketch and the other outlines of heads on this page, I am indebted to Professor R. S. Lull and to the Yale University Press. Pithecanthropus flourished about 500,000 years ago and is believed to have made use of fire and simple flint implements.

Of later date is the dawn-man, Eoanthropus, of Piltdown, England, who lived about 250,000 years ago. His bones seem to be the most ancient remains of man in England and occur, associated with crude stone implements and the remains of several

Trinil man

Piltdown man

Neandertal man

Crô-Magnon man

animals long since extinct. Another ancient type of man is the Neandertal, or Mousterian man, evidences of whom have been found in many European localities. These remains date from about 100,000 years or more ago. Of still later time is the Crô-Magnon man, believed to be of the same species as ourselves. His period may be set at some 25,000 years ago, and his blood may still flow in the veins of certain European peoples. He was remarkable for his great height, being commonly over six feet tall. His stone implements were of good workmanship, and his engraving, painting, and sculpture show him possessed of æsthetic traits and of unusual powers of expression. His remains have been found in Wales, France, and Spain. These few examples show how rich and numerous are the traces of primitive man.

That man has descended from an ape-like stock no reasonable person can doubt. He shows this affiliation in his body and in his activities in a thousand ways, and yet more than most animals, he has peculiarities of his own. When we look at civilization as represented in the complex life of cities and of nations with all their commercial interrelations, with their humane institutions such as asylums and hospitals, and with their opportunities for intellectual, æsthetic, and spiritual growth, it seems as if an attempt to base this enormous structure on an evolutionary foundation, with Lamarckism, Darwinism, and the like as driving forces, is futility in the extreme. Who for a moment would attempt to account for the Divine Comedy as a product of evolution? And yet, if evolution means anything, it means exactly this. Some-

where in the scope of its totality evolution must find a place for the highest achievements of the human soul, or the general conception crumbles. Every thorough-going evolutionist believes this and looks to the natural history of man, when viewed in its all-inclusive light, as the real history of man.

But how is it that man holds such an exceptional place in the world? We are quite sure that never before in the history of the earth has there arisen an organism that has probed the universe as man has, that has developed art, poetry, religion, and science as the human species has done and is doing to-day. Not that these accomplishments are in any sense final or ultimate, for no one can tell what the future has in store, but compared with the efforts of the long geologic past they are stupendous. We look with admiration on the bee

and the ant, and we are astounded at the instinctive capabilities of many animals, but, when we examine ourselves closely, we find most of these potentialities within us and a host more of capacities of which no lower creature seems ever to have dreamed.

In what respects has man lifted himself so much above his neighbors? Man is first of all a social organism. He is banded together in families, clans, and nations and, as thus organized, he resists the vicissitudes of life vastly more successfully than he possibly could single handed. As an organization, human society is in many respects unique. Social life was tried eons ago by the simpler animals in a thousand different ways; protozoan colonies out of which sexuality grew, sponge colonies and coral colonies which have had a hand in moulding the earth's surface, insect colonies

such as the ant hill and the bee swarm, all these preceded human society by untold ages. Wheeler informs us that in the insects alone social states have arisen no fewer than twenty-four different times in as many different groups of these animals. Yet none of these societies accomplished what man, as a social organism, has achieved.

They almost all differ from human society in two fundamental aspects. First of all, the members of most animal societies are close-blood relatives. In the ant hill the individuals are commonly the offspring of one queen; they are all sisters in one household. In almost all animal colonies, except the human, this close-blood relationship holds. Second, among the colonies of lower animals the division of labor is relatively slight. In human society occupations

mount into the tens of thousands at the very least. Among the other colonial animals the classes of performance are to be counted at most in scores. In the beehive, the drones have as their one duty the fertilization of the queen, the queen is serviceable only in that she lays eggs, and finally the worker performs the ordinary duties of caring for the young, procuring food, cleaning the hive and the like. Compare for a moment the relative simplicity of even so complex a situation as that in the beehive with the enormous intricacies of human life and civilization, where blood-relationship is most diverse and performance is specialized to an almost incredible degree. These aspects of human society set it in strong contrast with the social organizations of all other animals.

Another feature, in which man

differs from most animals, is in his striking ability to use the environment to his advantage. The primitive acquisition of fire made available to him such gigantic forces as we see in steam, electricity, and their endless applications. Who would have suspected that the unclad savage, as he warmed himself over the dying embers, was nursing a form of energy that was to do for man all that modern machinery has done! Little do we think as we look at a watch face that shines in the dark that the changes going on there foreshadow, in germ, possible sources of energy for future man that may be as much superior to fire as fire was to ancient brawn. But this may be so, and it is precisely this capacity to discover and utilize to the utmost such environmental changes that makes man different from almost all other organisms.

In harnessing the energies of nature man has discovered and perfected tools. Few other animals use tools. Monkeys and apes have their sticks and stones, but it took man to fashion them into serviceable shapes, to discover metals, to build engines, steamships, and airplanes. Man's tools were amongst his first possessions and not till he acquired the habit of preserving them and passing them on to future generations did society progress. The race that buries with the primitive artisan the choice objects of his life's work never goes forward. Even the rude tools of one generation must be put in the hands of the next, if real progress is to be made. In this sense the inheritance of property separates man from most other animals.

Another trait in which man is peculiar is in the possession of a com-

plex language. The lower creatures have their cries as outlets for emotional states, and these cries form a simple kind of organic language. Everyone knows the difference between the hum of a complacent and of an angry bee. How diverse and informing are the vocal sounds of a dog. All these are types of primitive language, but they are almost endlessly remote from human speech which, as represented in written form, is not only a means of communication between distant individuals but the stabilizer of all past events, the vehicle of history. From this standpoint the simple organic language of the lower animals fades into insignificance.

Finally, though not last, for there are many other points of contrast between man and other animals, the human species has acquired the habit

of teaching, of passing on to a new generation the practices and the wisdom of the older generations. This is largely a human institution, for few animals other than man possess the least trace of it. Very many animals learn. Beasts, birds, frogs, and fishes learn; even an earthworm can learn to find its way out of a simple maze. Such animals learn by individual experience; they do not learn by example. To learn by example is to have a model and this is at once the worth and the artificiality of the teacher. Man learns not only by experience as the lower animals do, but also by being taught and the profession of teacher is almost exclusively a human profession. Contrary to the belief of the commonalty, animals, other than man, do very little teaching. In a beehive worker bees, that have never seen a queen reared, will make queen

cells and hatch queens with as much skill as the best. Their operations are largely instinctive. Such performances are not taught, though bees like most animals of their grade can learn.

Thus, man, though an animal, is preëminent in a multitude of ways as compared with his neighbors. He has the most intricate and complicated form of social life of which we have any knowledge. He controls his environment, devises and uses tools, and acquires property as no other organism has ever done. He has developed a most complex spoken and written language which serves him for communication and record, and he teaches as well as learns. No wonder with all these exceptional traits that he appears so strikingly unlike other animals. It is therefore to be expected that his evolutionary relations will be far from usual.

When we ask ourselves how important natural selection is in human affairs, and whether man's life progresses with no show of the inheritance of acquired characters, we pass immediately into a situation where everything that the biologist has taught seems to be contradicted. At every step human society seems to have gone forward by the inheritance of daily acquisitions and all our humane institutions, charities, and the like cry out against such an ideal as natural selection. This reversal of affairs is, however, merely apparent.

Every scheme in evolution, whether it be Lamarckian or Darwinian in its tendencies, turns on the transmission of traits, on heredity, and when we inquire what and how man inherits, we find him as peculiar in this respect as he is in others. A child may inherit, for instance, a book from its

parent which means that this particular book is passed from the parent dead to the child living. This is the literal significance of the term inherit. But less tangible things than a book may be inherited; the child may inherit the parent's habits of thrift and frugality or of poor table-manners. Such an inheritance involves learning through example and applies to an enormous number of social customs. Finally the child may inherit the color of the parent's eyes or his stature or the like, and this form of inheritance, which involves a rather figurative use of the term, we know to be germinal. The eyes, unlike the book, are not handed on from parent to child, but a tendency is transmitted whereby the child's eyes develop the color of those in the parent. This tendency, as we know, is passed on by the egg or the sperm. Almost no other animal than

man inherits as we inherit a book, and few animals inherit as we do thrift or table-manners, but all animals inherit as we inherit eye-colors and the like. This type of inheritance has been called germinal, or organic, and may be contrasted with the other types of inheritance which have been called social, for they depend primarily on man's social condition. Human inheritance, then, like other human capacities, is more complex than inheritance in lower animals, for it includes in addition to their type of inheritance, social inheritance.

Organic or germinal inheritance involves the physical traits of our bodies, hair-color, eye-color, size, tendencies and resistances to disease and, less physical in character, temperament and the like. Many of these peculiarities are inherited in accordance with Mendelian principles; they

are subject to mutational change and to natural selection. The part Lamarckism plays in their moulding is as little known in man as in other animals.

Social inheritance includes our social customs, our language and the way we use it, our daily habits of honesty or dishonesty, frugality or wastefulness, and such minutiae as eating food with a knife or using a napkin. All these features are learned either through experience or from a teacher. None of them comes to us through the sperm or the egg. Language, one of the most fundamental, never reaches us as a germinal contribution, but must be learned by each generation as it matures. To these traits natural selection has no application except in a figurative way, for though an individual may gain a mate and offspring in consequence of his

table-manners, there is no certainty that any of his descendants will show these traits as they may his eye-color or hair-color. Social inheritance is accomplished on what may be described as a Lamarckian model, for the habits of one generation are modified and, as such, are handed on to the next. But this, of course, is through what one individual learns from another and not through the germ, so that when we speak of it as Lamarckian we are using that term in a figurative way.

The methods of social inheritance, then, are very different from those of germinal inheritance. They have a superficial resemblance to the Lamarckian conception, and probably it is this resemblance coupled with our great familiarity with them in daily life that predisposes us to the Lamarckian doctrine. It is a strange

fact, but nevertheless true, that in the estimation of character or in the formation of friendships we are more likely to be influenced by social than by germinal inheritances. The color of the hair or the color of the eye is under such circumstances of less importance to us than the speech or table-manners. Thus human inheritance and in consequence human evolution extend over a wider field than the corresponding operations in lower animals and man's uniqueness again reasserts itself.

But though we are in this respect above the rest of creation, we are still subject to the common law. Not an epidemic sweeps through a community without leaving behind it, in the young members of the population, a selected race whose partial immunity will have its effect on the coming generation. This is especially noticeable

in the arrival of a new disease. The first coming of Europeans to America is said to have brought to the native Indian a variety of entirely novel maladies. Among these was smallpox. This disease is said to have run like wildfire among the natives and to have reduced their numbers to an almost incredible level. Measles is another disorder of the same kind. To the Aleut Indians, of the extreme Northwest, this is a disease of great severity and has been known to have exterminated whole villages. Yet to Europeans it is a mere bagatelle due doubtless to the long exposure of this race to it and to the partial immunity acquired in the course of time through selection.

The social habits of man have not only had their influence on the kinds of inheritance that he has developed, but they have impressed his nature

and in fact that of every other social organism, in a way too often overlooked. All such organisms are of necessity coöperative. It is inconceivable that a social state should exist otherwise; in every sound state there must be coöperation between its members. In fact the so-called solitary animals show more or less coöperation, and it is this primitive condition that reaches a much higher level of development in all social forms. Wheeler has very justly emphasized this feature in the life of the insects. It is commonly overlooked that, among most animals, coöperation is as usual a form of response as competition, and in social organisms, it is of necessity a primary form of response.

In consequence of his social proclivities, we find, in the evolution of man, a large body of permanent altruistic action which in the form of

benevolent acts, charities, and the like, is intended to extend the life of those who otherwise might meet a speedy end. Viewed from what might be regarded as a biological level this practice at first sight would seem to demand condemnation. Why not follow the example of the ant and destroy all defectives? Surely this would give added resources to those who are most able to use them. But a wholesome human society could not exist under such circumstances. Such an act as the destruction of the weak would be so subversive of the coöperative principle, not to mention the higher virtues, that a state endorsing such a practice would disintegrate and fall.. This principle is so clearly recognized that civilized man has always striven, and rightly striven, to succor the unfortunate.

Yet if one takes the trouble to look

through any group of public hospitals or asylums, he cannot help but be impressed with the heavy burden of wreckage there represented. In a harsh world natural selection would have removed much of this, but the hand of public benevolence has intervened and warded off the stroke. Nevertheless, every one must see that if such a weight as this be sufficiently increased, society may be crushed by it. The situation is not an academic one, but has already begun to bear heavily on legislatures and through them on the public. What may be done to meet, in a humane way, such a situation? That the state should arrange for those who, in their weakness, come upon it as public wards to live the length of life that nature allots them is indisputable. But that such individuals should be restrained from perpetuating their kind is like-

wise reasonable. It will probably soon come to be a recognized function of the state to guard against offspring from those of its wards who, because of serious heritable incapacity, are on its hands. How this is to be accomplished — through segregation, sterilization, or some other effective means — is a practical question that communities may sooner or later be called upon to settle. In the performance of this duty society, like natural selection, will concern itself not so much with the life of the individual as with what that life may transmit to future generations.

Thus man's nature though in many respects apparently contradictory to that of the animals below him is after all grounded on the same basic principles. He has evolved far beyond the vast majority of creatures and though he has reached a level where

conduct is directed in new ways and under novel conditions, he is nevertheless still subject to the old laws. There is after all only one kind of life in the universe.

VI

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